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Spatio-Temporal Analysis of Environmental Noise in Institutional Area

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Abstract*: Environmental noise is identified as unwanted sound arises mainly from motor vehicles. The increasing number of motor vehicles in institutional area would negatively affect the environment and students learning process. This study assesses the variability of environmental noise in institutional area in terms of temporal and spatial analysis. Noise level was taken in Universiti Malaysia Terengganu (UMT) campus by using sound level meter at varying time intervals of 0700hrs - 1000hrs (morning), 1100hrs – 1400hrs (afternoon) and 1500hrs – 1800hrs (evening) and noise mapping was constructed by using Surfer14® and SketchUp® software. L_{max} (78.8 dBA, weekday (WD) and 84.4 dBA, weekend (WK)), L_{Aeq} (75.0 dBA, WD and 75.5 dBA, WK), L_{min} (43.9 dBA, WD and 41.3 dBA, WK), L_{10} (66.8 dBA, WD and 58.5 dBA, WK) and L_{90} (47.5 dBA, WD and 44.4 dBA, WK) were evaluated. Motor vehicles from Class M (cars and buses) shows strong correlation with noise level (Spearman's correlation coefficient, r=0.74, p<0.01, WD) while Class L (motorcycle) shows strong correlation (Spearman's correlation coefficient r=0.59, p<0.01, WK). The finding from this study is important for UMT management team to control noise pollution in campus in line to reduce noise exposure towards university students and staff.

***Index Terms*: Correlation, Environmental noise, Institutional area, Motor vehicles, Sound level meter.**

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I. INTRODUCTION

Nowadays, there are many developed and developing countries. It is a good sign that the countries are moving forward but at the same time, it will take more pollutants and pollution regarding on human activities such as construction, traffic density, and urbanization. Among the many forms of environmental pollution that may affects the cities, noise pollution is often underestimated. It is clearly detected that noise directly impacted human health over 6 decades ago. Extreme or high noise exposure might induce the hearing loss in human of auditory organ in the ears [1]. Noise extremely can affect the process of learning in class which directly disturb the process of gaining the knowledge [2]. Variety locations will produce different levels of noise. Educational institutions are one of the areas that are sensitive to the noise pollution. High level of noise can directly impact the learning process, especially towards school children [3]. Noise pollution not only affected the students in primary school but also students in secondary and tertiary schools. Universities have no exception facing the environmental noise. The main contributor to the environmental noise in universities was said to be traffic noise because almost all of the students and staff have their own vehicles. It is important for students to have a conducive place to learn and gain knowledge. Nonetheless, noise level increases with the increment of motor vehicles in universities. The capabilities of student in learning performance has been found diminish due to high noise levels in educational centers [4]. Educational area in university is where the teaching staff and students spend their most time working. Therefore, the high concentration of traffic road at the area will affect their psychology and physiology wellbeing with regard to noise emitted from motor vehicles. Thus, this study is conducted in order to assess the variability of environmental noise in institutional campus in terms of temporal and spatial in University Malaysia Terengganu.

II. MATERIALS AND METHODS

This study was conducted at University Malaysia Terengganu which is in Kuala Nerus District of Terengganu State with the coordinate of 5°24'27.10"N and 103° 5'16.87"E as shown in Figure 1.

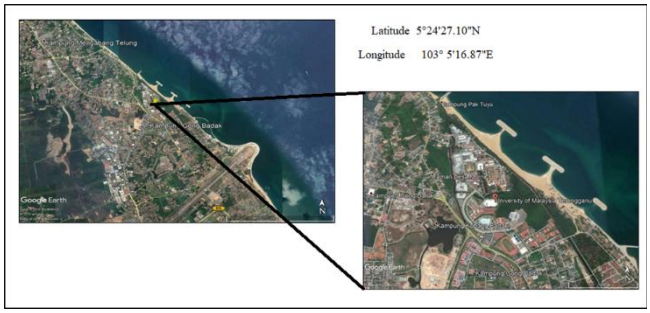

Fig 1. Study Area

The evaluation of environmental noise inside the UMT campus involved the sound pressure level measurement and noise mapping. The noise level was measured at 37 different locations which randomly selected as indicated in Figure 2. The noise measurement was conducted for three days on working days and three days on weekend from 0700 hrs until 1800 hrs. Measurement time (interval) for each of the 37 points inside the campus is 5 minutes. Suitable time for sampling was verified through the pilot study prior the real sampling campaign. Pilot study is a small scale preparatory study performed in order to assess plausibility, time, cost, adverse occasions, and enhance upon the study plan preceding execution of a full-scale research venture [5].

Fig 2. Sampling Points

The parameters that were measured in this study are noise level, wind speed and the number of motor vehicles. The sampling campaign uses Sound Level Meter (SLM) for monitoring of noise level. It is a hand-held device equipped with a microphone. The fluctuation of sound waves caused the difference in air pressure will then responds by diaphragm in the microphone and the movement of the diaphragm will convert into electrical signal. The electrical signal then will change into sound pressure back and display the resulting sound pressure level in unit decibels (dB) [6]. The measurement of noise level was taken by using Extech sound level meter model 407730 that comply with IEC 61672 Class 1 standard. The measurement of noise level was used the "A" weighted scale [7]. The A-weighting curve has been widely acquired for environmental noise devices, and is standard in many sound level meters. The A-weighting system is utilized in any measurement of environmental noise such as roadway and aircraft noise. A-weighting is also in common use for evaluating potential hearing damage caused by extreme noise. Decibels indicate the loudness of a sound. Thus, the units for the measurement of noise level was expressed in dB(A) or dBA.

Before reading is taken, the sound level meter was calibrated according to the manufacturer instructions. The SLM shall not be exposed to the direct sunlight and rain while in use. Microphone was set up on a tripod remain at a tallness of 1.5m over the ground at a point of around 70 degrees, in any event 1.0m from any reflecting surface, and wind speed shall not exceed 5 m/s [3]. The wind speed during the sampling was measured by using the Kanomax Climomaster 6501 multi-function hot wire anemometer. The wind speed was measured simultaneously with the noise level. The wind speed reading shall not be more than 5 m/s because the noise level recorded may be inaccurate as the noise level will mixed with the wind noise. The number of motor vehicle was measured by using tally marks system. Motor vehicles were divided into several classes which are class L (motor vehicles with less than four wheels), class M (motor vehicles having at least four wheels and used for the carriage of passengers), class N (motor vehicles having at least four wheels and used for the carriage of goods), class O (trailers, including semi-trailers), and class T (tractors) based on Malaysian Standard created by SIRIM Berhad (The Classification and Definition of Power-Driven Vehicles and Trailers) (2005) [8]. The number of motor vehicles that passing on the road was counted manually.

Data were analyzed by using Microsoft Office Excel 2010 to establish the descriptive statistics such as the average of noise level, maximum (Lmax) and minimum (Lmin) level of noise. The equivalent sound levels, LAeq was calculated by using the following Equation (1);

$$L_{Aeq} = 10\,Log \sum_{i=1}^{i=n} 10^{(\frac{L_i}{10})} * t_i \qquad (1)$$

Where,
n = total number of samples taken;
L_i = noise level in dBA of the ith sample and;
t_i = the fraction of total sample taken.

L_{max} and L_{min} are the maximum and minimum of noise level throughout the monitoring campaign. The noise level dataset is then being arranged in increasing order in Microsoft Office Excel 2013. L_{10} and L_{90} were computed in Microsoft Office Excel 2013 by entering the accompanying command; [= PERCENTILE (array, k)], select array from the organized noise data and insert k=0.9 for L_{10} and k=0.1 for L_{90} (Ismail et al., 2015). Data were analyzed to produce noise mapping for spatial analysis. To construct noise map, the dimension of the study area was determined especially building location and the sampling points. After all the information obtained, a proper drawing which included building locations and sampling points were drawn by using SketchUp® software. After the noise level has been analyzed, the noise mapping was drawn using the Surfer® version 11 software and overlaid with the plan layout drawn via SketchUp® earlier.

Statistical Package for Social Science (SPSS®) version 25 software containing correlation analysis was used to establish the relationship between motor vehicle contributing to the noise level. Correlation coefficient (r) measures the relationship between two parameters or variables. The evaluated will be in the range of +1 and -1, which represent the strength of relationship between parameters. The equation of r for sample is defined as Equation (2);

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}} \qquad (2)$$

Where, n = total number of samples taken;
x_i and y_i = the individual sample points indexed with i

III. RESULTS AND DISUSSION

The noise level in UMT with different surrounding activities during weekday and weekend are shown in Figure 3 and Figure 4. The results show that receptor in UMT is exposed to equivalent noise level (L_{Aeq}) of 68.9 dBA on weekday and 69.4 dBA on weekend. Thus, the L_{Aeq} levels are exceeded the limit (55 dBA) stated in guideline by Department of Environment (DOE). This is mostly since that there were many motor vehicles passing the main road in UMT that dominated by motorcycles and cars. A study to determine the noise pollution on university campus of Ataturk University by Özer et al., (2014) [4] has founded that the noise levels measured were exceed the permitted value due to the heavy vehicular traffic is rising including a large number of buses. The L_{max} is higher during weekend rather than weekday because the receptor was exposed to the sound of adzan from the mosque as the sampling point is nearby. Previously, Omubo-Pepple et al., 2010) [9] clarify that, one of the major sources of noise pollution is the public address systems (loudspeaker) utilized by religious and social associations. Figure 4.2 shows the noise level patterns of six timespans at selected sampling locations. The noise level of morning, afternoon and evening during weekday were higher than weekend as shown in Figure 4.2, where there exists statistically significant difference ($p<0.05$) between weekday and weekend. The noise level of weekday morning is higher than afternoon and evening periods because a total of 276 units of motor vehicles entering UMT starting from 0700hrs until 0900hrs as the staff and students starting to get work at 0800hrs. According to Mehdi et al., (2011) [10], the noise level was generally soaring during mornings and evenings which the mean value of noise levels is over 66 dB because of the shuttling pattern of Karachi citizen.

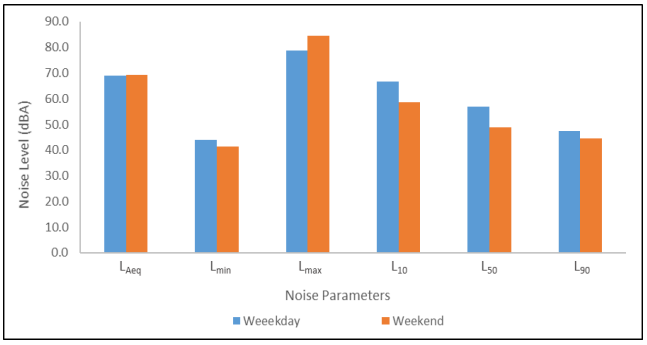

Fig 3. Noise indices

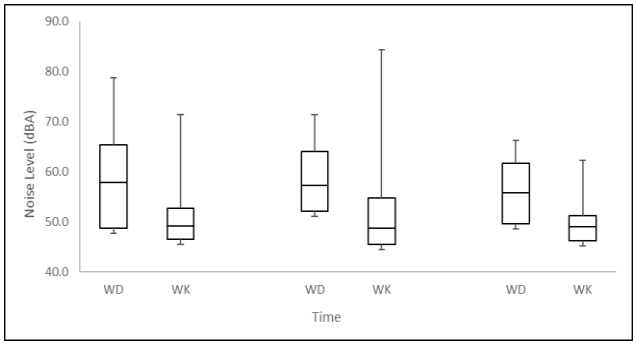

Fig 4. Comparison of noise level between peak hour of weekday and weekend

Noise maps of the University campus were drawn and overlaid with 3D spatial map considering the noise values obtained from the six measurement times and real world coordinate of the 37 locations in UMT. The red color represented the most critical point of the noise exposure and the blue color shows the lowest value of noise exposure. Figure 5(a) shows the noise map of weekday morning which the time taken is from 0700hrs until 1000hrs. The red zone Figure 5(a) indicates the highest level of noise is found within the area of the entrances to the campus which are the UMT main hall (Dewan Sultan Mizan) and chancellery. The zone that indicated the high level of noise is range from 65 dBA to 78 dBA which is above the limit set by DOE. According to previous study by Zannin et al., (2013) [2], the road that interfaces the doorways to the campus shows overwhelming noise levels above 70 dBA, thus being the primary noise source inside the campus area.

Figure 5(b) shows the noise level in UMT is 8.1 dBA lower than the weekday morning. The noise level at area near the main entrance of UMT is between 60.6 dBA and 71.4 dBA because the cleaning staff mainly enter the campus within 0700hrs until 0800hrs to their designated place to work. This is because the sampling day for weekend is taken on Saturday. Normally private sector workers are taking a shot at Saturday and off on Friday [3]. A total of 30 units and above motor vehicles passing by the road within the time range. There are also a few group of lecturers and students entering the campus as they might have extra classes or programs held in the UMT. Figure 5(c) shows the noise map of weekday afternoon which the time taken is from 1100hrs until 1400hrs. The noise level dominating the main road connecting the three entrances of UMT shows the high level of noise causes by the increase of road density within the time range. Vehicle counts expanded amid the morning surge hour and peaked at noon, with a moderate decrease for the rest of the evening [11]. Therefore, the noise level is higher with the increase of road density. The maximum noise exposure during this time is 67 dBA to 73 dBA. Figure 5(d) shows the noise map of UMT during weekend afternoon. The noise level in UMT is moderate as compared to weekday afternoon. There are many areas that have noise level in range of 42 dBA to 52 dBA. The highest level of noise recorded was 84.4 dBA at 1323hrs caused by the sound of adzan.

Figure 5(e) and Figure 5(f) shows the noise maps during weekday and weekend evening which time taken is between 1500hrs to 1800hrs. At this time, the noise exposure is critically affected at the area around the main entrance towards student's residential area for both weekday and weekend. This is because the number of motor vehicles is increasing as student and staff are on their way back home after class and office hours. According to the six different time of measurement, the noise levels in UMT are exceeding the limit stated in guidelines and it will affect the psychological and physiological of students and staff. High noise exposure of noise (more than 50 dBA) as documented by World Health Organization (WHO) can cause health effects to human [10]. Morning and evening shows higher noise levels than afternoon on weekend as shown in the spatial mapping Figure 5(a)-5(f). The noise levels of weekends were lesser than those of weekdays especially on weekend afternoon [11].

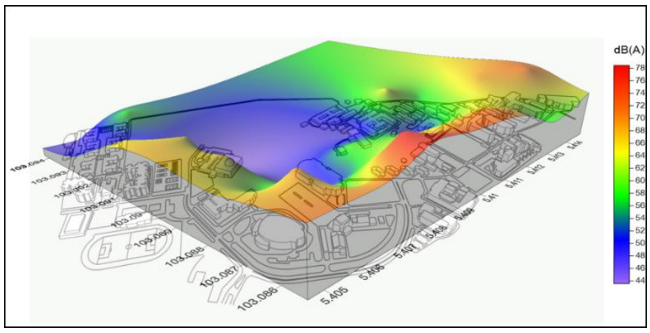

Fig 5(a). Noise map of UMT during weekday morning

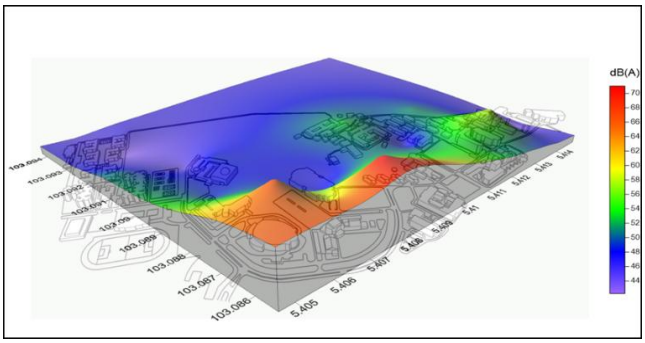

Fig 5(b). Noise map of UMT during weekend morning

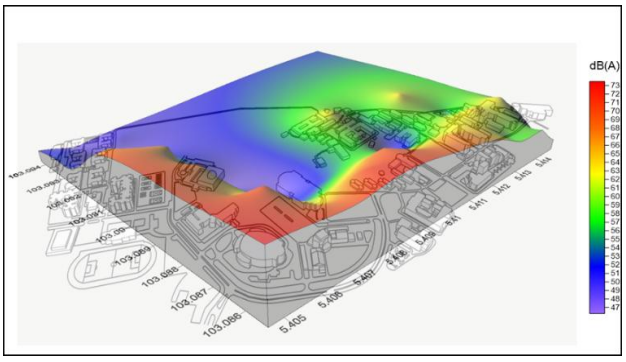

Fig 5(c). Noise map of UMT during weekday afternoon

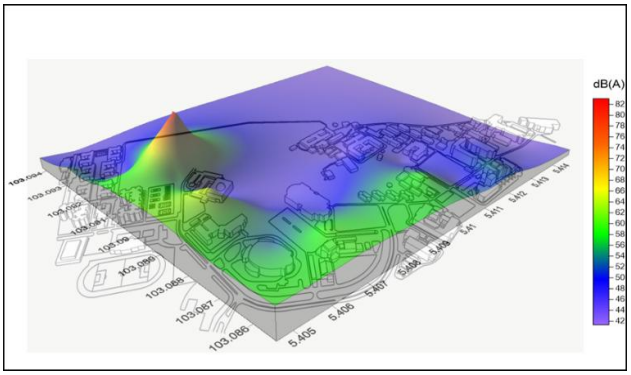

Fig 5(d). Noise map of UMT during weekend afternoon

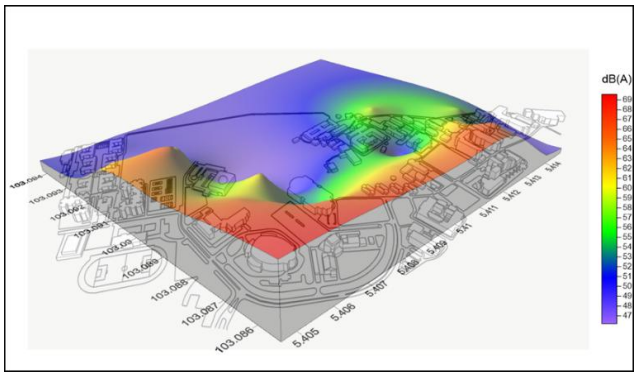

Fig 5(e). Noise map of UMT during weekday evening

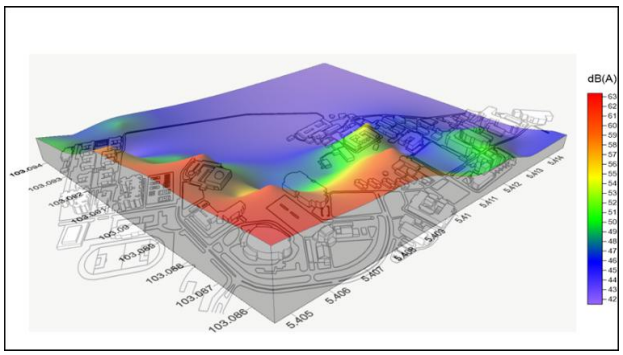

Fig 5(f). Noise map of UMT during weekend evening

The Spearman correlation coefficient conducted by using SPSS® version 25 software showed the relation between two parameters as the dataset is nonparametric [12]-[13]. To correlate the number of motor vehicles with noise level, the traffic count is divided in to several classes of motor vehicle which are Class L, M, N, O and T based on SIRIM Berhad. Table 1 shows the correlation between noise level and motor vehicle classes on both weekday and weekend.

Table 1. Correlation coefficient of noise level and motor vehicle classes

Parameters	Noise Level	Class L	Class M	Class N
Noise Level	1			
Class L	0.639**	1		

Class M	**0.708** **	**0.773** **	**1**	
Class N	0.185 **	0.150 *	0.225 **	1

** Correlation is significant at the 0.01 level (2 tailed),
* Correlation is significant at the 0.05 level (2 tailed)

The loading factor of more than 0.50 is considered as strong, range of 0.40 – 0.49 is considered as moderate and less than 0.30 is considered as weak [12]. Results showed that there exists strong significant correlation between noise level and Class L (motorcycles) ($r=0.639$, $p<0.01$), noise level and Class M (cars) ($r=0.708$, $p<0.01$), noise level and class N (lorries) ($r=0.185$, $p<0.01$). Previously, Morelli et al., (2015) [14] found there is significant between noise values and traffic counts ranged from 0.54 to 0.72. The positive relationship between number of motor vehicle and noise level is a reason to worry, as it can affect the health of students and staff. Class O and T (trailers and tractors) have no significant with the noise level as they do not enter the UMT area or only once in two weeks the tractors are used to transfer the goods in the campus. Therefore, Class L and M become the main contributor to the noise level in UMT campus. Light vehicles on most local road such as motorcycles and cars normally influence the noise emission as the speed of the light vehicles is impressively higher, and therefore contributes to the noise emission [15]. Traffic calming such as yellow transverse strip and speed hump also one of the elements that contribute to the traffic noise. Speed hump and yellow strips produce high vibration and noise level as the motor vehicles travel at high speed through it. The design concept of hindrance such as speed hump is to control vehicular speed and high vibration level is normal when a vehicle passes over it at higher speed than the allowable limit [15].

IV. CONCLUSION

There are several locations in UMT which exposed to the noise level above the limit stated by Department of Environment in Planning Guidelines for Environmental Noise Limits and Control which the limit is 55 dBA (LAeq) for sensitive area like institutional area. The equivalent noise levels in UMT on both weekday and weekend morning are higher than both afternoon and evening. Noise maps generated show the critical point is found within the area of main hall and chancellery which is near the main entrance of UMT. This is because the noise exposure is mainly from the increasing in the number of motor vehicle passing by the road. There exists strong significant correlation between noise level and traffic volume. Class L (motorcycles), Class M (cars) and Class N (lorries) shows positive relationship with noise level. Class L and M (strong correlation) becomes the main contributors to noise pollution in UMT campus.

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